Fetal Scalp Blood Analysis

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Fetal blood analysis (FBA) is more than 20 years old. It is not only an essential part of modern supervision of the fetus during labor, but from the historical point of view it is the method which first enabled us to examine the fetus directly before birth, namely by analysing its blood.

Task of FBA as a clinical procedure

FBA is a method which should be employed only as a complementary measure to continuous cardiotocography.
It enables us:

1. to clarify whether or not biochemical changes confirm imminent fetal hypoxia and/or acidosis; and
2. to help in deciding whether further important clinical consequences like tocolysis (inhibition of uterine contractions) or termination of the labor by operation are necessary.

In this way it is possible to achieve a minimum of operative deliveries which is of advantage to the mothers, with an optimum of safety for the fetus.

From our many years of experience and in my own personal view, the consistent use of fetal blood analysis could have avoided some of the problems and criticisms which occurred in some countries during the past few years in connection with intensive cardiotocographic supervision during labor and the increased caesarean section rate.

Remarks on the technique

For optimal results of FBA and for safeguarding of the fetus the following technical points must be especially considered:

a) After drying the skin of the presenting part, sterile parafin should be applied with a swab. The parafin film helps to produce a thick drop of blood at the point of incision.

b) The incision should be made with a jabbing motion, not deeper than 2 mm.

c) The blood sample should be taken during the first half of the contraction if possible, but on no account immediately after the contraction, since the lowest levels occur at this time.

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d) The blood samples are best withdrawn when the patient is lying on her side, which is the easiest position and prevents vena cava syndrome. We recommend that the parturient hold her heel against the medial epicondyle of the opposite tibia and straddle her legs wide apart.

e) We use a glass capillary about 30 cms in length, which has a dry heparinized cotton thread on the inside.

f) To prevent dangerous fetal bleeding the point of incision should be observed after the blood sample has been taken until the next contraction starts. The blood flow should stagnate or be very slight.

Suitable parameters for the clinical supervision of the fetus

For purely clinical purposes it is sufficient to make only blood pH measurements. Blood gas measurements can be dispensed with, since simultaneously with the occurrence of O_2 insufficiency, there is also a CO_2 increase (respiratory acidosis) and thereby a measurable rise in the H+ ion concentration. Later on O_2 insufficiency leads to an increase of lactic acid content and to a metabolic acidosis of the infant through anaerobic glycolysis. Both kind of increases in acidity can be ascertained by pH measurements (Fig. 1).

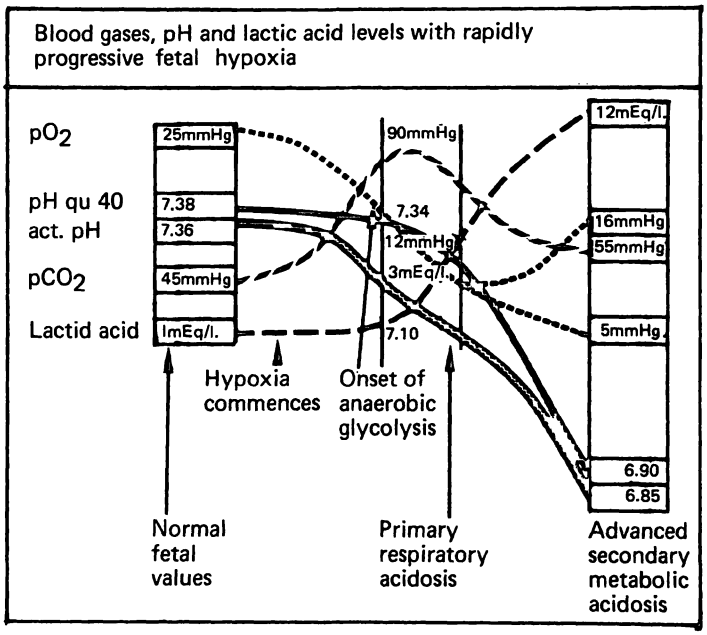


Fig. 1

Blood gas measurements, in particular the growing possibility of continuous transcutaneous measurements in the fetus, can provide interesting additional information; however, their specific characteristics must be known in order to avoid confusion.

CO_2 measurements can sometimes be misleading, particularly in advanced intrauterine complications, because after the start of anaerobic glycolysis the CO_2 production diminishes, while in reality the intrauterine complication proceeds. Furthermore, a total interruption of the supply from mother to fetus occurs very seldom; usually there is a partial metabolic exchange. In this way the CO_2 is partially eliminated and therefore the pCO_2 level can decrease, as shown in Fig. 1.

In a similar way blood O_2 measurements can be misleading since

there are situations with almost normal blood O_2 levels in spite of advancing acidosis. The reason for this can be found in the O_2 conserving adaptation of the fetal circulation, a kind of centralization (25) which we described in the '60s. The total oxygen consumption is reduced in such cases and leads to a slight increase in pO_2.

As already mentioned simple pH measurements are adequate for clinical routine purposes. The choice of apparatus should be made accordingly. Expensive, complicated machines for micro blood samples which measure a number of values from the acid-base balance and the blood gas tensions tend to be frequently out of order and need expert maintenance and care. For this reason we prefer - for the normal daily routine - pH meters set up in the labor ward that can be kept in running order by members of our own staff.

Suitability of fetal blood samples

As long ago as 1966 Desai et al. (9) reported a good correlation between pH blood gas values in samples taken from the newborn scalp and from a branch of the temporal artery so that they recommended scalp samples for monitoring newborn. Later Adamsons et al. (1) showed that there was an excellent correlation in experimental animals between blood samples from the scalp and from the carotid or jugular arteries. Between 1964 and 1970, Bowe et al. (5), Gare et al. (11), Kubli et al. (14) Teramo (29) and ourselves (4) all found that there was a good correlation during labor between values in human fetal blood samples and those in the umbilical vessels. O'Connor et al. (19) recently published - as far as FBA is concerned - a dissenting view. However in the meantime several comments from various authors, namely Furi and Beard (10), Philip (21), Rooth and coworkers (23), including a contribution from ourselves (28) have disproved these statements. Our publication of 1976 (4), apparently unknown to O'Connor et al. pointed out that even in cases of moderate or marked caput succedaneum the correlation between the pH of scalp and of umbilical arterial blood was surprisingly good. Concerning actual pH, r was 0.78 and for pH after equlibration, r was 0.79.

What do fetal scalp blood samples express?

We analyze microblood samples from the peripheral circulation. The composition does not differ too much from arterial blood, because the arterio-venous difference in the peripheral circulation is estimated as being relatively small of account of the low metabolism in the skin. There is no difference in the composition of the blood between arteries to the brain and those supplying the scalp, as they both receive blood from the same main branch of the aorta. Of course, it would be more informative to analyze venous blood from those organs of special interest, for instance from the brain. However, this is scarcely possible in routine clinical work. However, for diagnostic purposes it is important to know that particularly in

chronic hypoxia the fetus undergoes the already mentioned O_2 conserving adaptation of its circulation, and as a result of this pathophysiological mechanism the supply to the brain and heart is affected much later; other organs, such as the skin, muscles and intestines are subjected to a reduced O_2 supply much earlier.

It is known from the pathophysiology of the cerebral circulation, that even in cases of significant changes of blood pressure in the body circulation, a stable supply of blood to the brain is maintained, through the highly adjustable autoregulation of the brain circulation (15). Accordingly, we can assume that generally before the brain circulation is affected there will have been disturbances in the periphery, for instance in the muscles, leading to anaerobic glycolysis and to the overproduction of lactic acid. Thus, through fetal blood analysis and the falling pH values, we get warning signs early enough, and can draw the necessary conclusions.

It is still not clear, however, whether - as Mann and coworkers (16) found - an isolated severe cerebral ischemia can occur with substantial head compression accompaned by bradycardia, with subsequent permanent psycho-motor impairment of the child. Follow-up examinations of children with increased intracranial pressure showed higher incidence of abnormalities only after more than 20 hours of protracted labor (17). From these results it can be concluded that relatively short lasting head compression does not seem to be seriously dangerous.

Indications for FBA

In our department a fetal blood analysis is indicated when the following heart-rate patterns are present:

heart-rate pattern	time	pre-condition
acute bradycardia	immediately	presenting part not yet on the pelvic floor or in the pelvic outlet, as then a vaginal operation to terminate the birth should be performed without FBA
alarm-dips (late, variable, early if >60 bpm)	after 3 dips or at the latest after 10 mins.	

Explanation of indication diagram:

In cases with acute bradycardia before the first 10 minutes after the occurrence of this suspicious heart-rate pattern, fetal acidosis occurs in about 17%. Therefore, blood samples must be taken immediately. In all other suspicious patterns this is not necessary until after 10 minutes have elapsed (Fig. 2)

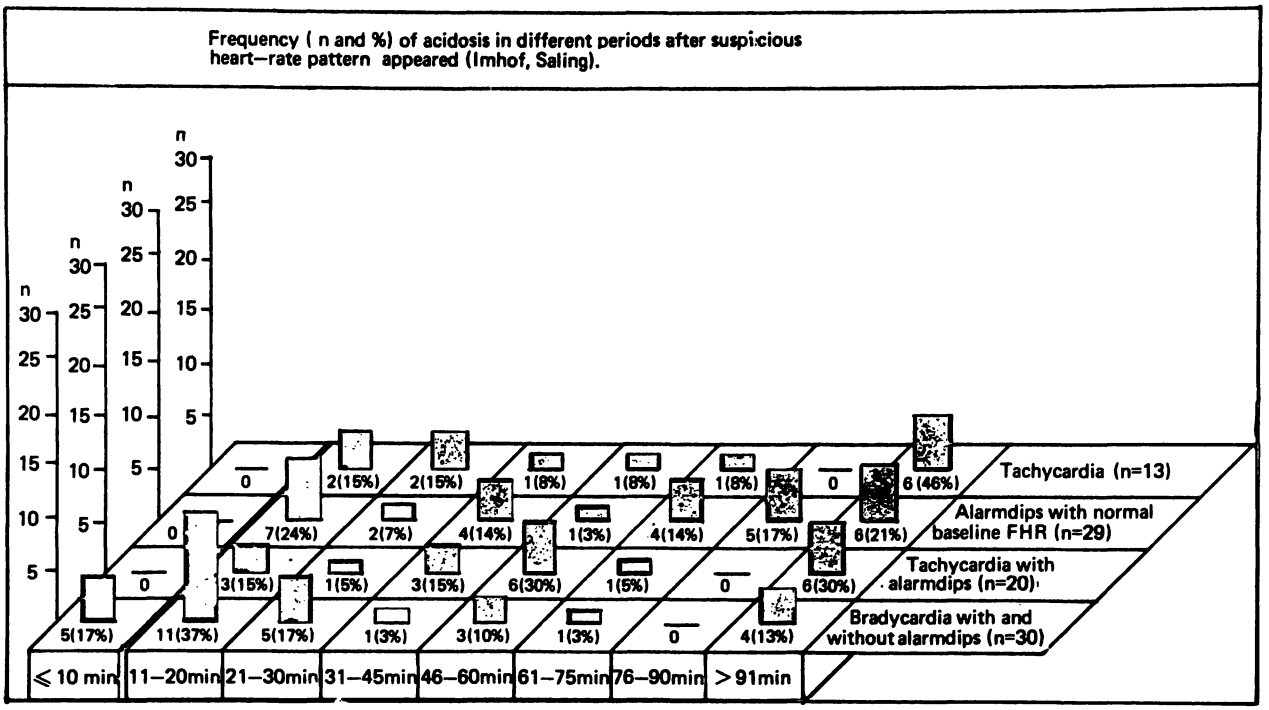


Fig. 2

Repetition of FBA and clinical consequences

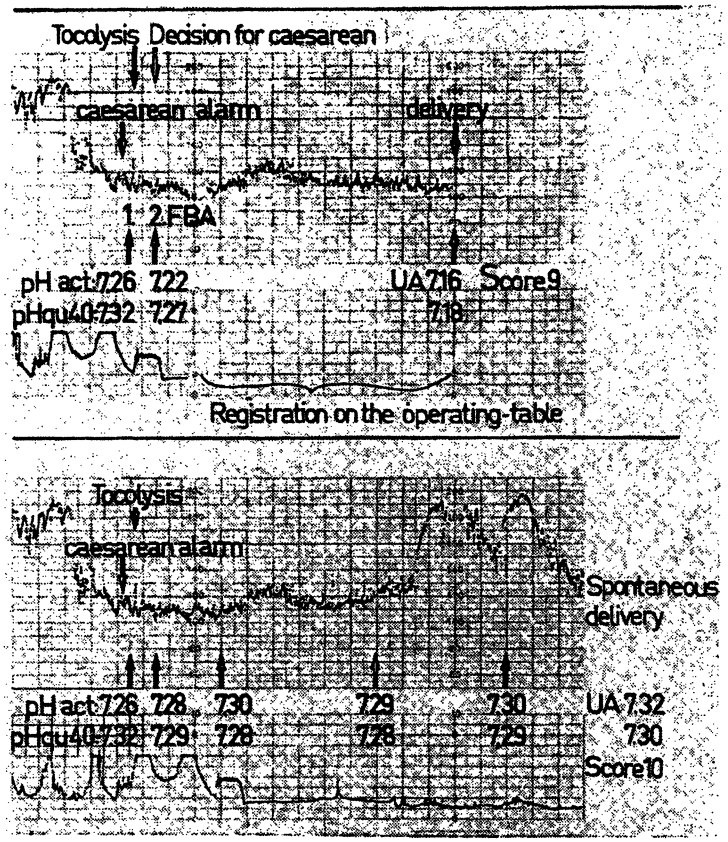
This point will be discussed in greater detail because there is apparently a degree of uncertainty about it. FBA should be repeated depending on the character of the assumed disturbance.

When an acute complication (occurrence of acute bradycardia) is suspected, it is recommended to take a blood sample as quickly as possible, then immediately a second one and if necessary a third. Examples are shown in Fig. 3.

In order not to lose any time in cases with hypoxia, two other measures should be taken at the same time:

a) inhibition of the contractions through tocolysis;
b) alarm should be given for the operative team to be ready in case an emergency caesarean section should be necessary.

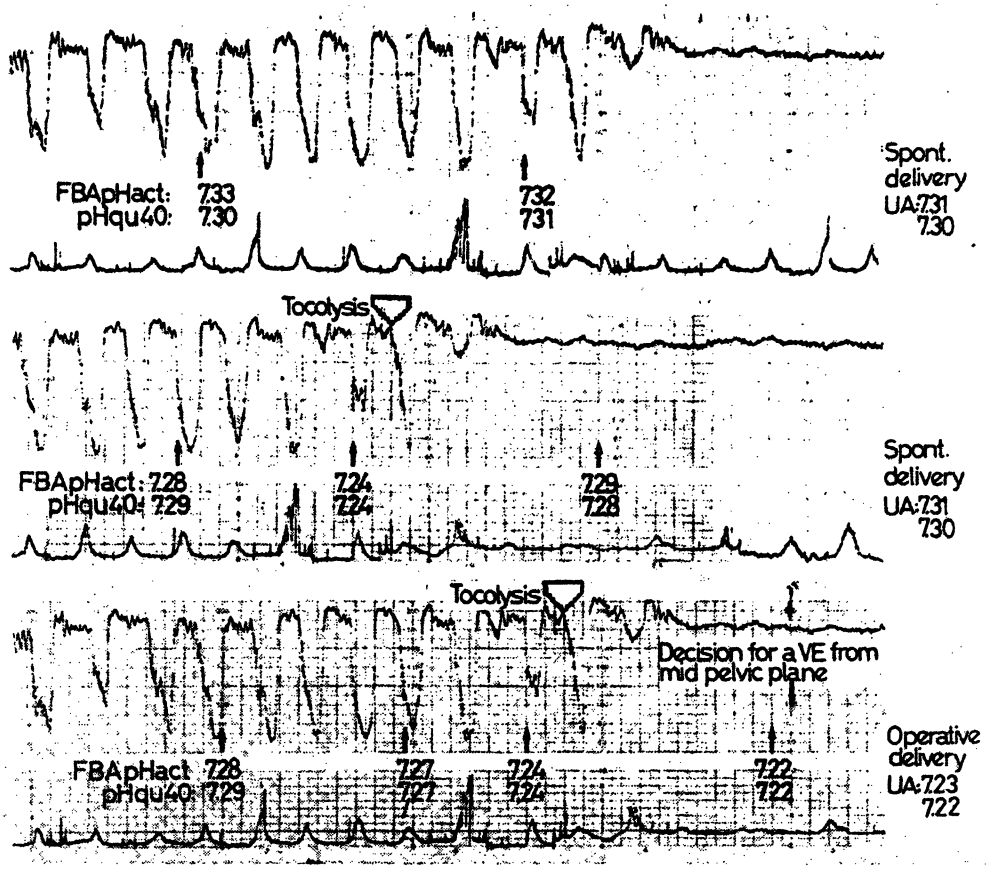
If further fetal blood analyses do not show a critical fall in pH, then one should wait (Fig. 3 lower part). Usually the fetal heart-rate pattern recovers within a short time. As such non-hypoxic episodes often happen due to mechanical irritations of the umbilical cord, it is recommended in addition to tocolytic therapy, to change the position of the parturient. If however the pH values decrease in spite of preventive measures (Fig. 3 upper part), a caesarean section should be performed immediately, or if the labor is so far advanced, a vaginal operation should be done to deliver the baby.



Model of the correct management
Bradycardia with indication for caesarean (above)
Bradycardia without critical pH-decrease (below)

Fig. 3

All other suspicious heart-rate patterns indicate a slowly advancing complication. Examples are shown in Fig. 4. The first FBA should be made after about 10 minutes. When alarm-dips are persistent, particularly if the pattern becomes more marked, and the first pH value was not suspicious, further blood samples should be taken at intervals of about 15 minutes (Fig. 4 upper case). If the pH values remain suspicious after 2 or 3 samples have been taken, and if the heart-rate pattern concerned does not occur again in a stronger or more marked form, then further FBA - if at all - can be made at longer intervals. If a pH value of less than 7.3 was measured from the first blood sample after suspicious decelerations have occurred (Fig. 4 case in between), then the blood analysis should be repeated at short intervals of 5 to 10 minutes in order to establish the trend of the blood acidity reaction. Tocolytic therapy should be started concurrently if there is a further fall in pH values. When the intensity remains the same or when the suspicious heart-rate patterns disappear, the intervals between the blood sampling can be gradually lengthened and finally further blood analysis can be dispensed with if the pH values increase again.



Correct conduction of labor in the early second stage (model)

Should the pH values continue to decrease to prepathologic or even to pathologic values in spite of tocolytic therapy (Fig. 4 lower case), an operation to terminate the labor should be performed.

There is one possibility which should be excluded namely the so-called maternogenic increase of fetal acidity. This situation is caused by overflow of lactic acid from the mother to the fetus. Maternogenic acidity increase is not as dangerous as acidosis caused by fetal hypoxia. Therefore it is not necessary to terminate the labor immediately by operation. To rule out such cases with maternogenic origin of acidity increase we recommend to measure maternal and fetal metabolic acidity, namely the so-called pHqu40. This is the pH measured after equilibration of the blood samples with 40mmHg pCO_2.

If the difference between mother and fetus is less than 0.05 pH units, maternogenic acidity increase is confirmed. Rooth and coworkers (22) recommended to use Δ pH actual, i.e. if pH-act. difference is less than 0.15 units, a maternogenic acidity increase is probable. We are currently evaluating the comparative reliability of these methods.

It is of course impossible to give recommendations for every situation that may occur during labor. The points discussed should be regarded merely as practical guidelines.

Possible failures

Every clinical method has its possible failures. In order to prevent serious misinterpretations it is important for the clinician to recognize the possibility of errors and the many causes of these errors. Tab. 1 gives a general idea of the most important failures possible in connection with fetal blood analysis. Our publication on this appeared in 1974 (26). The error rate lies at 1% taking all single pH analyses into account, and at 2.4% taking the number of supervised fetuses into account (7). The result can be regarded as satisfactory.

1. In connection with pH–measurement	2. Biological causes	3. During sampling	4. During storage of blood samples	5. Through calculation
a) Calibration b) Equilibration c) Thermostatisation d) Electrode e) Reading of results	a) Variation between contraction and interval b) Caput succedaneum c) Fever	a) Exposure to air b) Admixture with air	a) Autoxydation b) Sedimentation	a) Addition of too divergent pH–values

Tab. 1

Fetal blood examination in cases of erythroblastosis

We first recommended FBA in erythroblastosis in 1961 (24). If severe erythroblastosis is suspected from ΔOD-450 values and from the antibodies in the amniotic fluid, it is recommended to withdraw a fetal blood sample right at the beginning of the labor in order to perform the Coombs test and to obtain the hemoglobin content. If the Coombs test is positive and anemia is present of less than about 12g%Hb, then preparations should be made to perform a blood exchange transfusion immediately after delivery. In this way the infant's blood group can be established before it is born. Another fetal blood sample is used for cross-matching after the blood of the donor is available. In most cases it is possible to complete all the necessary preparatory measures before the infant is born, so that about 10 minutes after delivery, as soon as the umbilical vessels have been catheterized, the blood exchange can be started. This diagnosis before birth and the resulting immediate start of the blood exchange transfusion is of great advantage to infants who are severely affected by erythroblastosis.

Risks of fetal blood analysis

As far back as 1970 Balfour and coworkers (2) published a report about the potential dangers of fetal blood analysis with a short literature review and some of their own cases.

Primarily, there is a slight increase in the risk of infection. The invasion of bacterial flora into the amniotic cavity in-

creased - according to Dahler and coworkers (8) - faster due to cardiotocography alone, than without this measure. In addition, fetal blood sampling required repeated vaginal digital and instrumental manipulations. Local infections such as scalp abcesses at the site on incision, and pustules have been reported. We have introduced a new procedure to reduce the danger of infection during the intensive supervision during labor (27). It employs a continuous rinsing of the lower birth canal with a PVP-iodine solution. A thin plastic catheter is attached to the scalp electrode which is applied for internal cardiotocography. PVP-iodine is very slowly pumped into the vagina and afterwards resorbed by a sanitary towel.

Another rare but serious danger arises from continuous bleeding from the incision. Beard and coworkers (3) have reported on two infant deaths and Bretscher (6) reported one death. The causes were faulty technique (the incision was too deep) and also coagulation defects (twice). Hull (12) has published details concerning the question of perinatal haemorrhage as being a cause of complication for FBA, and has observed one case himself (13). How seldom such a serious complication does in fact occur can be seen from our figures: of the 13,500 cases supervised by FBA (up to July 1980) not a single infant bled to death.

Other complications reported are that the incision blade broke and that occasionally cephalhaematoma occurs.

Results of combined intensive supervision during labor

The overall performance of an obstetrical unit today can be assessed with the following parameters which are available and are realistic criteria in routine work:

1. perinatal mortality and mortality during labor;
2. assessment of the newborn by APGAR score and routine pH measurement in umbilical arterial blood;
3. caesarean section rate;
4. incidence of low birth weight infants;
5. incidence of high-risk cases.

Today our special interest concerns the results achieved through modern intensive supervision during labor (cardiotocography and fetal blood analysis). The mortality during labor, assessment of the newborn immediately after delivery and the caesarean section rate play the main role for this consideration. Our fetal mortality rate during labor during the last twelve years, since we have used cardiotocography as a routine measure in nearly all cases combined with fetal blood analysis, averaged 0.15% (Tab. 2). This is minimal particularly if we compare it with the mortality during labor before introduction of fetal blood analysis. This mortality was 58 out of 7045 born infants from 1955-1960, or 0.8% (20).

During 1961-1967, when cardiotocography was not available, we

Mortality during labor			
Methods of Supervision	Only Auscultation	Auscultation and FBA	CTG and FBA
Year	1955–1960	1961–1967	1968–1979
Number of deliveries	n = 7045	n = 18326	n = 25501
Number of fetal deaths	n = 58	n = 58	n = 39
%	0.8	0.32	0.15
Signific.		$p < 0.001$	$p < 0.001$

Tab. 2

combined fetal blood analysis with simple ascultation of the fetal heart rate by stethoscope. During this period we had a mortality during labor of 0.32%. The caesarean rate during the past ten years in our department has remained between 7 and 11%, which is quite acceptable.

The number of fetuses and newborn seriously endangered by hypoxia is very low due to intensive supervision during labor. One can assume that there is a serious hypoxic risk to the infant when the umbilical cord arterial pH values are below 7.1 and the infant is simultaneously in a moderately or seriously clinical depressed condition; i.e. an Apgar score of less than 4. The number of such newborn in our clinic has been 0.27% during the past seven years, since we pay particular attention to prevent severe fetal acidosis. Which positive effects with the combined intensive supervision during labor can be achieved by paying high attention to the assessment of the state of the newborn can be seen from Fig. 5.

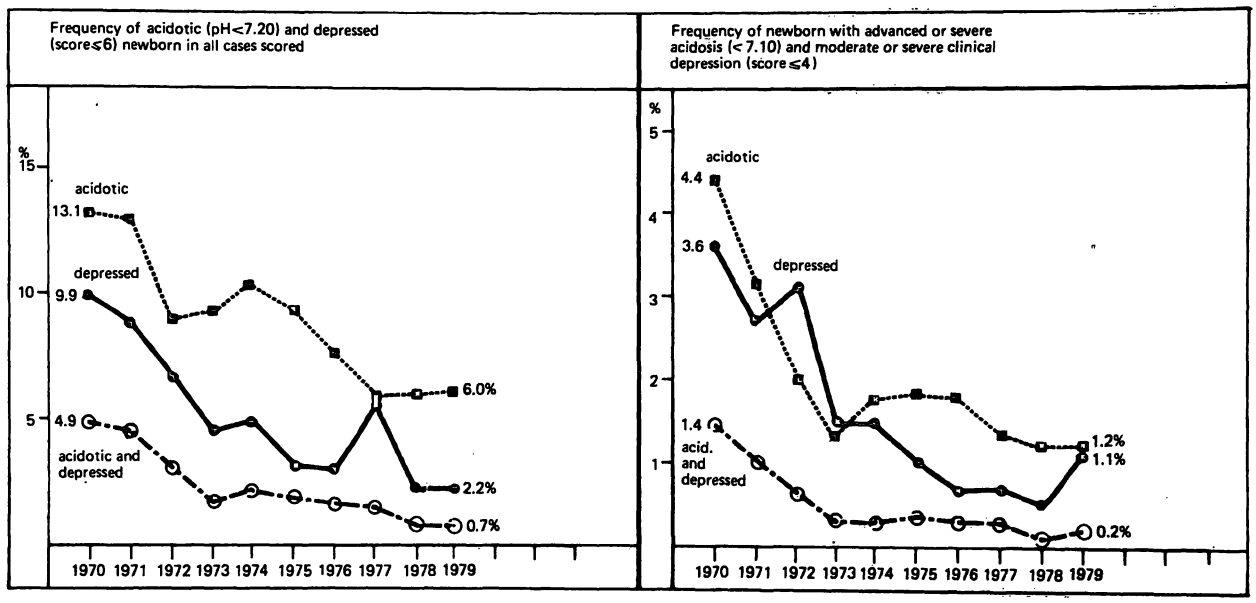


Fig. 5

In 1970 we started measuring the umbilical artery pH in every newborn infant after having measured this parameter since 1962 in every high-risk infant. Our perinatal mortality rate in a department with a high proportion of high-risk cases (84%) lies - since 1973, when we opened a neonatal intensive care unit - at about 1.2%, as determined by WHO standard criteria.

With this review we hope we have been successful in giving some up-to-date information about important questions concerning FBA and have been able to demonstrate which benefits can be achieved by combined biochemical and biophysical intensive supervision during labor.

REFERENCES

1. ADAMSONS, K., R.W. BEARD, R.E. MYERS: Comparison of the composition of arterial, venous and capillary blood of the fetal monkey during labor. Am.J.Obstet.Gynecol.107 (1970), 435
2. BALFOUR, H.H., S.H. BLOCK, E.T. BOWE, L.STANLEY JAMES: Complications of fetal blood sampling. Am.J.Obstet.Gynecol. 107 (1970), 288
3. BEARD, R.W., E.D. MORRIS, S.G. CLAYTON: Haemorrhage following foetal blood sampling. J.Obstet. Gynaec.Brit.Cwlth. 73 (1966), 860
4. BOENISCH, H., E. SALING: The reliability of pH-values in fetal blood samples: a study of the second stage. J.Perinat.Med. 4 (1976), 45
5. BOWE, E.T., R.W. BEARD, M.FINSTER, P.J. POPPER, K. ADAMSONS, L.S. JAMES: Reliability of fetal blood sampling. Am.J.Obstet.Gynecol. 107 (1970), 279
6. BRETSCHER, J.: Pränatale Diagnostik. In: Schwalm, H. und Döderlein, G.: Klinik der Frauenheilkunde und Geburtshilfe. Urban & Schwarzenberg, München-Berlin-Wien 1970
7. CHMELIRSCH, G.: Möglichkeiten der Fehlerentstehung bei Routineuntersuchung von Fetalblut. Auswertungen eines größeren Materials empirischer Daten. Dissertation an der Freien Universität Berlin, 1980
8. DAHLER, R., K. DECKER, H.A. HIRSCH: Bakterielle Besiedlung des Fruchtwassers unter der Geburt: 1: Einfluß des internen CTG; Sectio-Morbidität. In Perinatale Medizin, Bd. VI, 7. Deutscher Kongreß f. Perinat. Med. Berlin, 1974. Thieme, Stuttgart 1975
9. DESAI, S.D., R. HOLLOWAY, A.K. THAMBIRAN: Blood samples from ear-lobe puncture. Lancet(1965),1126
10. FURI, L., R.W. BEARD: Capillaries in the fetal scalp. Lancet I (1980), 483

11. GARE, D.J., C.G. WHETHAM, J.D. HENRY: The validity of scalp sampling. Am.J.Obstet.Gynecol. 99 (1967), 722

12. HULL, M.G.R.: Perinatal coagulopathies complicating fetal blood sampling. Brit.Med.J. 4 (1972), 319

13. HULL, M.G.R., J.A. WILSON: Massive scalp haemorrhage after fetal blood sampling due to haemorrhagic disease. Brit.Med.J. 4 (1972), 321

14. KUBLI, F., D. BERG, G. KÖHNLEIN, J. HÜTER, D. BRETZ: Die Mikroblutuntersuchung am Fetus. 1. Kritik der Methode. Geburtsh. u. Frauenheilk. 26 (1966), 1537

15. LÜBBERS, D.W.: Physiologie der Gehirndurchblutung - Größe der Gehirndurchblutung; in Gänshirt, H.: Der Hirnkreislauf. Thieme, Stuttgart 1972

16. MANN, L.I., A. CARMICHAEL, S. DUCHIN: The effect of head compression on FHR, brain metabolism and function. Am.J.Obstet.Gynecol. 39 (1972), 726

17. McINTIRE, M.S., W.H. PEARSE: Follow-up evaluation of infants delivered by electronically recorded forceps delivery. Am.J.Obstet.Gynecol. 89 (1964), 540

18. NELSON, G.H., H.S. WAGES, D.A. HAHN, E.M. AZIA, D.S. FREEDMAN: A complication of fetal scalp blood sampling. Am.J.Obstet.Gynecol. 110 (1971), 737

19. O'CONNOR, M.C., F.E. HYTTEN, G.D. ZANELLI: Is the fetus "scalped" in labour? Lancet II, (1979), 947

20. PAKZAD, M., E. SALING: Perinatal Mortality of infants with signs of foetal distress before the introduction of the new methods of obstetrical surveillance. Germ.med.mth. XIV (1969), 499

21. PHILIP, A.G.S.: Transcutaneous pO_2 and the fetus. Lancet II, (1979), 1189

22. ROOTH, G., R.McBRIDE, B.J. IVY: Fetal and maternal pH measurements. Acta Obstet.Gynec.Scand. 52 (1973), 47

23. ROOTH, G., O. FALL, R. HUCH, A. HUCH: Capillaries in the fetal scalp. Lancet I, (1980), 369

24. SALING, E.: Die Zwei-Katheterverfahren für den Blutaustausch beim Neugeborenen. Dtsch.med.Wschr. 86 (1961), 294

25. SALING, E.: O_2-conserving adaption of the foetal circulation. Modern Trends in Paediatrics 3 (1970), 51

26. SALING, E.: Possible errors in fetal blood analysis and their prevention. In: Gluck, L.: Modern Perinatal Medicine. Year Book Medical Publishers, Inc., Chicago 1974

27. SALING, E.: Ein neuer Weg zur Senkung der subpartualen Infektions-Gefährdung. Bücherei des Pädiaters, Heft 80. Enke, Stuttgart 1978

28. SALING, E.: Capillaries in the fetal scalp. Lancet I (1980), 370

29. TERAMO, K.: The validity of foetal capillary blood samples during labour. Gynaecologia 167 (1969), 511

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